ANNUAL SUMMARY OF PHYTOPLANKTON BLOOMS AND RELATED CONDITIONS IN THE NEW JERSEY COASTAL WATERS SUMMER OF 1999

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Executive Summary

Phytoplankton monitoring is conducted annually in a Jersey's coastal waters and major estuaries for the presence and abundance of potentially harmful all species. The sampling has historically been conducted biweekly from May to September. During the 1999 summer season, as has been the case in recent years, diatoms (not normally associated with harmful effects) were the dominant phytoplankton forms over all. An exception to this has been in the Barnegat Bay - Little Egg Harbor area, where recurrent blooms of minute (picoplankonic) algal species have caused brownish water discoloration in recent summers. In 1999, a heavy bloom of *Aureococcus* sp. (the brown tide species) occurred in early summer, followed by similarly intense blooms of *Nannochloris* sp. *Nannochloris* is normally a dominant species in the Barnegat system. These two species are not considered toxic to humans, but they may have other harmful effects on aquatic resources. In the Hudson-Raritan estuary and New Jersey coastal areas, blooms of several species (both flagellate and diatoms) historically have caused nuisance blooms, some of which have led to hypoxic conditions and consequent fish kills. None of these, however, have been of the acutely toxic varieties.

Introduction

The New Jersey Department of Environmental Protection (NJDEP), Office of Water Monitoring Management, each summer monitors phytoplankton assemblages and red tide blooms in its coastal waters and major estuaries as part of New Jersey's compliance with the National Shellfish Sanitation Program (NSSP). The National Shellfish Sanitation Program requires that each coastal state develop a contingency plan that includes control measures for marine biotoxins [1]. Filter-feeding molluscan shellfish, known as “bivalves”(clams, oysters, and mussels) are capable of accumulating toxins that may be produced by certain algal species. The phytoplankton-monitoring program complements this portion of New Jersey's contingency plan, through surveillance of shellfish growing areas for possible toxin-producing algal species, which are identified and enumerated along with other phytoplankton present.

The primary purpose of this program is to ensure that shellfish harvested in New Jersey are not toxic for human consumption due to the presence of certain phytoplankton known to produce toxins. However, algal blooms may have other harmful effects including marine fauna kills, mild toxicity to bathers and reduced aesthetic quality. This information, most of which is obtained cooperatively with the US Environmental Protection Agency (EPA) Region II during their summer New York Bight Water Quality helicopter survey [1a], is summarized for the 1999 season. These results complement the extensive bacteriological monitoring and pollution source surveys conducted by NJDEP as part of the NSSP [1]. They also complement the offshore dissolved oxygen and bathing area bacteriological data, gathered by the USEPA. Also involved are the DEP Atlantic Coastal Bureau of the Division of Watershed Management and the shore county health agencies [3]. Further information regarding this monitoring plan may be obtained by contacting the Bureau of Marine Water Monitoring at (609) 748-2000.

Routine helicopter surveillance by the USEPA, with sample collections in coastal waters of the New York Bight, commenced in 1977 following the massive offshore bloom of *Ceratium tripos* a non-toxic dinoflagellate, which was associated with oxygen depletion and consequent widespread fish mortalities [4]. Prior to this, bloom incidence had been primarily estuarine or coastal. Beginning in 1973, the NJDEP and the National Marine Fisheries Service (NMFS) Sandy Hook Laboratory conducted an intensive phytoplankton survey of the New Jersey northern estuarine and coastal area [5]. Late spring and summer red tides, caused by several species of phytoflagellates, especially *Olisthodiscus luteus*, *Katodinium rotundatum* and *Prorocentrum* spp. have been recurrent in this region since the early 1960's. The blooms often extended from the Hudson-Raritan estuary southward along the NJ coast, sometimes as far as Belmar or beyond. The blooms have been associated with hypertrophication in the region [6].

Adverse effects were usually only aesthetic in nature (water discoloration and resultant accumulations of brown foam or floc) albeit occasional fish kills via hypoxia, or complaints by bathers of minor irritation, did result. The dinoflagellate "green tides" of 1984-85, caused by *Gyrodinium* cf *aureolum*, were the first serious blooms along the southern New Jersey coast; these were associated with several cases of mild sickness in bathers, and a few localized kills of benthic fauna [7, 8]. Also in 1985, yellowish-brown water caused by the minute chlorophyte, *Nannochloris atomus*, became conspicuous in the Barnegat Bay system and has recurred each subsequent summer [9]; the principal consequence has been diminished aesthetic quality of the water. Following these later events, routine surveillance was expanded southward from Island Beach to Cape May. A history of bloom events in New Jersey waters, and the phytoplankton species involved, is given in previous reports [1a]. Of the major blooms mentioned above, only those of *Prorocentrum* spp. and *G.* cf *aureolum* were associated with mild irritation or discomfort to bathers. Most instances of distress or mortality to marine fauna were attributed to hypoxia from decomposition, rather than toxicity, of the algae. To our knowledge, algae-derived toxins, associated with acute illness in humans via consumption of fish or shellfish, have not been detected in New Jersey waters; however, a few species known to be toxic in other regions have formed a portion of our coastal phytoplankton community. These will be discussed in the latter part of this report.

In recent years, major phytoflagellate red tides have been confined primarily to the Hudson-Raritan estuary. Here, however, diatoms (e.g. *Skeletonema costatum and Thalassiosira spp*.), normally most abundant during the cooler months, have dominated from mid to late summer. From 1996 to 1998, flagellate red tides were overshadowed by dense summer blooms of several diatom species in the estuary and, to a lesser degree along the adjacent New Jersey northern coastline. In 1995, the minute "brown tide" alga, *Aureococcus anophagefferens*, associated with damage to shellfish crops in eastern Long Island (NY) embayments, was documented in bloom proportions for the first time in New Jersey, in lower Barnegat Bay and adjacent Little Egg Harbor Bay [10]. Adverse effects were seen on the growth of juvenile clams. In 1996 and 1998, *A. anophagefferens* was detected here only in low numbers, but the species bloomed again in 1997 and 1999. The green tide (*G.* cf *aureolum)*, reappeared in our coastal waters in 1996 and 1997, but to a lesser extent than previously, being most concentrated in the Atlantic City - Ocean City area. No green tide was observed in 1998 or 1999.

Methods

The current survey encompasses the entire New Jersey coastal region, including the major estuaries at the northern and southern extremes. A total of twelve stations are sampled routinely for phytoplankton. These include six of those (JC11, 35,57,65,77 and 89) from the USEPA New York Bight NJ Beach Network (see map, "New Jersey's Coastal Phytoplankton Monitoring Network"), concurrently with bacteriological sampling, three sites from the Hudson/Raritan estuary network (RB56, 51 and 15), two in Barnegat Bay (BB1 and 2) and one in Delaware Bay (DB1). In 1998, sampling was performed a total of eight times, approximately every two weeks, from late May through August. In response to the appearance of brown tide blooms in 1995, two additional stations were added in the Barnegat system, one in the lower central portion (BB1A) and one (BB3) in Little Egg Harbor Bay, which is adjacent to lower Barnegat Bay; in 1997, stations 3A (Little Egg Harbor at Tuckerton) and 4 (Great Bay) were included. Supplementary samples were also taken in coastal or estuarine locations on occasions where green or red tide blooms were observed or suspected.

Members of the USEPA, Region II Monitoring and Surveillance Branch (Edison, NJ) made field collections via helicopter as in previous years. Samples were taken at a one-meter depth using a Kemmerer sampler. Coastal stations were sampled just outside the surf zone. In the Atlantic City area (JC77) supplementary samples for green tide were taken at mid-depth approximately one-half mile off shore (designated as site JC77A). Water aliquots for phytoplankton species composition/chlorophyll a remained iced, to be analyzed within 24 hours of collection. All procedures were in accordance with DEP standard field methods [12]. Phytoplankton identification, cell counts, and chlorophyll a analysis were performed according to Standard Operating Procedures (SOP) of the DEP Aquatic Biomonitoring Laboratory and adopted by the Bureau of Marine Water Monitoring. The Bureau of Marine Water Monitoring also performs year-round monitoring of coastal water quality at about 260 locations for parameters such as chlorophyll a, dissolved oxygen, salinity, transparency and nutrients. Sampling for these parameters is performed on a quarterly basis. The most recent report of this data is available at the Bureau of Marine Water Monitoring's web site at www.state.nj.us/dep/watershedmgt/bmw.

Staff from USEPA, and the Monmouth County Health Department, which also performs phytoplankton identification and enumeration, make ancillary measurements (e.g. dissolved oxygen, temperature). The NJDEP Atlantic Coastal Bureau of the Division of Watershed Management makes supplementary aerial observations. Limited brown tide data and observations were obtained from personnel of the National Marine Fisheries Service James Howard Marine Laboratory at Sandy Hook, NJ. Relevant observations from various sources are also directed to our office.

Results and Discussion

Table 1. 1999 Highlights

Sample Date	Event
May 27	
Raritan and Sandy Hook Bays	A moderate bloom of diatoms was detected including; *Rhizosolenia, Asterionella and Skeletonema sp.* Total cell counts were in the range of 15,000 to 20,000 per mL, with some resultant brownish water discoloration.
Barnegat Bay Area	Moderate bloom concentrations of the "brown tide" algae *Aureococcus* sp. were detected in lower Barnegat Bay and adjacent Little Egg Harbor, with concomitant brown water discoloration reported in this area. This species is not considered to be toxic, but it may have other harmful effects on aquatic resources.
June 16	
Raritan and Sandy Hook Bays	A moderate diatom bloom continued in this area. The dominant species was *Thalassiosira* sp.
Barnegat Bay and Great Bay	Concentrations of the "brown tide" algae (*Aureococcus* sp.) continued to increase. Highest cell densities (> 10^6) were in the lower bay, between Surf City and Manahawkin, and into Little Egg Harbor. The bloom extended southward into Great Bay, and northward to Forked River.
June 30	
Raritan and Sandy Hook Bays	Moderate bloom of diatoms continues in this area. Dominant species were *Thalassiosira, Skeletonema*, and *Cylindrotheca*.
Barnegat Bay and Great Bay	The "brown tide" algae (*Aureococcus* sp.) was still present, but cell counts were decreased somewhat to 10^6 cells/mL.
July 16	
New Jersey Coastal area	*Pseudonitzschia seriata* was identified in the ocean near Sandy Hook, but in low concentrations and not likely to pose a human health impact. This species is indigenous to mid-Atlantic coastal waters and is normally most abundant during the cooler months. Phytoplankton were otherwise at moderate levels.
Delaware Bay	A moderate diatom bloom was ongoing with a normally diverse species assemblage.
July 28	
Raritan and Sandy Hook Bays; New Jersey coast	A moderate algae bloom was ongoing with a mixture of diatoms, chlorophytes and flagellate species. A few of the flagellates, including *Katodinium* and *Prorocentrum* sp, have been associated with "red tide" (red water) although none are of acutely toxic varieties.
Barnegat Bay area	With the brown tide diminished, the other dominant alga, *Nannochloris* sp. was at near-peak concentrations. This minute chlorophyte has been responsible for the persistence of greenish brown water discoloration throughout the bay system in recent summers. No toxic effects are known from this species.
July 28	

Sample Date	Event
Southern New Jersey Coast	*Pseudonitzschia seriata* was present but at low levels , thus toxic effects are unlikely. Phytoplankton concentrations were otherwise moderate.
August 25	
New Jersey northern coast	*Pseudonitzschia seriata* was present, but in low numbers. *Prorocentrum micans*, a potential irritant to bathers, also was present, but in low numbers. Phytoplankton concentrations were otherwise moderate.
Other coastal areas were not sampled on this date due to high winds that prevented the helicopter from continuing to sample.	

Phytoplankton Species Composition/Bloom Effects

A list of major phytoplankton species for the 1999 season, with notes on occurrence and distribution, is presented in Table 2; spatial and temporal succession of dominant species are included. Species considered dominant occurred often in cell concentrations greater than 10^3 mL^{-1}. Blooms occurred when densities of one or more dominants approached or exceeded 10^4 cells mL^{-1}. Concentrations in this range of one species, or of several species combined, tend to impart visible coloration to the water, i.e. cause "red tide". For *Nannochloris*, (and others such as *Aureococcus*), because of their minute size (<5 *mm*), the criterion for blooms (10^5 mL^{-1}) is an order of magnitude higher than for the larger species. Cells of this small size range (mostly 1.5-3.5*m*m) are collectively termed picoplankton.

HUDSON/RARITAN ESTUARY

As in recent years, phytoplankton this season in the Hudson/ Raritan estuary was dominated by a diverse assemblage of diatoms in moderate bloom proportions. Dominant diatoms included *Rhizosolenia delicatula*, *Asterionella glacialis*, *Skeletonema costatum* and *Thalassiosira* sp. Two flagellates associated with "red tides" (red water) *Prorocentrum* sp. and *Katodinium* sp. were observed in the samples collected on 7/28/99, but these species were present only in low concentrations. Neither is known to be acutely toxic. No extensive red water blooms were reported for this season. No acutely toxic algal species were detected in the Hudson/ Raritan estuary during the 1999 summer season.

BARNEGAT BAY

The highlight of the 1999 sampling season in Barnegat Bay was the presence of an extensive "brown tide" bloom caused by the picoplankter Aureococcus *anophagefferens*. Reports of visual brown tide observations were received commencing in April, until July when it apparently subsided. Peak concentrations of *A. anaphagefferens* approaching 2×10^6 (the highest recorded thus far for local waters) were attained in late June. In July the "brown tide" diminished, allowing *Nannochloris* sp. to resume its dominant role. No acutely toxic algal species were found in Barnegat Bay during the 1999 season.

NEW JERSEY COASTAL AREA

Northern New Jersey coastal waters were characterized by moderate algal concentrations in 1999. Species composition was similar to that in the Hudson/Raritan estuary, although generally in lesser concentrations. An exception was *Pseudonitzschia seriata*, a potentially toxic diatom, which was present in ocean samples collected off Sandy Hook on 7/14 and 8/25, but at levels considered too low to be toxic.

Southern New Jersey coastal waters were generally clear, with moderate algal concentrations. *Pseudonitzschia seriata* was observed in southern coastal waters on 7/28, but again at relatively low levels.

The diatom *Pseudonitzschia seriata* is considered to be a causative agent of amnesic shellfish poisoning (ASP). It is indigenous to north and mid-Atlantic coastal areas, but it is usually present at levels too low to produce toxic effects.

DELAWARE BAY

Algal densities were elevated from mid to late summer, with the normally diverse assemblage of flagellate and diatom species. No acutely toxic algal species were detected in the Delaware Bay in 1999.

For historical information on algal conditions in New Jersey's estuarine and coastal waters, see the Annual Summary of Phytoplankton Blooms and Related Conditions in New Jersey Coastal Waters Summer of 1998[1a].

Biomass Measurements

As opposed to species differential cell counts, chlorophyll a measurements are reflective of total phytoplankton biomass. In the previous years of our survey, mean chlorophyll a levels, as well as seasonal variation, were generally greatest in the major estuaries at the northern and southern extremes of the New Jersey coast. This is attributed in part to tidal fluctuation, but even more to the intense bloom pulses that occur in these estuaries. In 1999, mean chlorophyll a levels again were highest in Raritan and Sandy Hook Bays and also in Delaware Bay (Figure 2, Table 3). Maps of seasonal chlorophyll a levels at sites in New Jersey's coastal and estuarine waters are included in the Appendix to this report.

Barnegat Bay historically has sustained moderately high chlorophyll a levels, with maxima in the range of 30-40 µg/L, 1999, however, saw the highest chlorophyll a values recorded thus far for the Barnegat Bay system. The peak value of 62.57 µg/L at site BB2 on June 30th was considerably higher than in previous years and the highest for all New Jersey sites in 1999.. During the month of June, the highest chlorophyll a concentrations were located in lower Barnegat Bay and Little Egg Harbor due to heavy brown tide presence there. By the end of July the higher concentrations were located in northern Barnegat Bay, with *N. atomus* and other species being responsible for the elevated levels. Chlorophyll a levels greater than $15 \mu g L^{-1}$, were observed through all seasons in Manahawkin Bay (see attached maps).

In coastal waters, chlorophyll a levels were generally much lower than in the estuaries and bays. Elevated values at some sites, such as in Monmouth and Atlantic/Cape May Counties, may reflect estuarine influence. In 1999 the mean Chlorophyll a concentrations were similar to those from 1998[1a].

In the Delaware Bay chlorophyll a concentrations peaked at the end of July and were lowest in the month of June. Mean chlorophyll a values for the entire season are shown for each station in Table 3.

Environmental Factors

For the past few summers, major phytoflagellate red tides have been confined principally to the Hudson - Raritan estuary; these have occurred in early summer, preceded and often followed by blooms of chlorophytes and diatom species [1a]. This is not surprising considering the affinity of our problem algal species for certain nutrient fractions, which are generally more available in the bays and estuaries than in seawater [6]. However, given the ample nutrient supply in the New York Bight region, it is surprising that the tendency of red tides to spill out of the estuary and be sustained in adjacent New Jersey coastal waters, has not been more evident in recent summers. In view of the fact that diatoms are normally dominant during the cooler months, the midsummer shift from flagellate to diatom dominance (as in recent years) may be weather-induced. This is supported by the fact that the same diatom species tend to be abundant simultaneously in both the estuary and adjacent coastal waters. Many of the phytoflagellate and chlorophyte species encountered are more characteristic of the estuarine/intracoastal areas, with lower salinity regimes than those found in nearshore ocean environs. The abundance of diatoms in the bay(s), however, may reflect a contribution from ocean waters via wind and tidal currents.

The nearshore waters of the New York Bight are subject to considerably greater turbulence and slower warming than the sheltered estuaries and embayments. Sustained southwesterly or northeasterly winds can promote upwelling or downwelling (respectively), and thus water column mixing, along the New Jersey coast [7]. Conditions such as these may persist in varying degrees during a given summer. Conversely, flagellate blooms, or red tides, in the coastal waters have typically developed under conditions of quiescence and warmth, which promote water column stratification and, ultimately, bottom hypoxia; likewise, the same conditions have prolonged the blooms in the estuaries and bays [1,7]. The recurrence of bottom hypoxia in certain areas, e.g. portions of Raritan Bay and one to three miles off the coast between Belmar or Manasquan and Seaside Heights [1a,2], is likely influenced by hydrographic patterns, which allow accumulation and deposition of decomposing phytoplankton from surrounding areas. Barnegat Bay, where intense blooms recur, is not well-flushed by tidal currents, as it is sheltered from the New York Bight by barrier islands; however, it is generally well-mixed due to its shallowness, precluding hypoxia in most cases. Diligent monitoring of oceanographic and meteorological conditions (i.e. water column temperature and salinity, precipitation and sunlight, wind direction and velocity) thus could aid considerably in prediction of red tide blooms and hypoxia where they have historically occurred.

Harmful Algal Species In New Jersey

We have observed red tides, or blooms of various species, in the Hudson-Raritan estuary and adjacent New Jersey waters for over three decades [1,6]. While some of these have been associated with bather discomfort, or adverse effects on marine fauna, none has resulted in severe human illness, such as paralytic shellfish poisoning (PSP) or several other possible syndromes. Such acute symptoms occur principally through consumption of seafood, especially filter-feeding shellfish, i.e. "bivalves" (clams, oysters, mussels), which have accumulated the algae and toxins [3]. A few marine phytoplankters (mostly dinoflagellates) known to be toxic in the northwestern Atlantic, and other regions, have also been found in the New York Bight and New Jersey coastal waters.

From our north, *Alexandrium tamarense* (formerly *Gonyaulax tamarensis*), causative species of PSP in waters of New England (especially the Gulf of Maine) and eastern Canada, has been found in New Jersey, but in low concentrations (max. $3x10^3$ cells L^{-1}). Somewhat higher concentrations have been found in nearby Long Island, NY. In 1986, a "red tide" of *A. tamarense* in Flanders Bay, with cell densities as high as $1.4x10^4$ L^{-1} (=14 mL^{-1}), produced levels of paralytic shellfish toxin (PST) in shellfish of 190µg /100g tissue [12]. The PST level for closure of shellfish areas in the US is 80µg/100g tissue [3]. Thus, very dense cell concentrations, or visible red tides, of this species may not be necessary for toxicity to develop. PSP is distributed worldwide in temperate waters, and also possibly in tropical waters. There is evidence that the toxin may affect various marine fauna, as well as humans [13]. Of the several species (mostly *Alexandrium*) known to produce PST, only *A. tamarense* has been found in New Jersey.

More recently, a diatom, *Pseudonitzschia* spp., has been implicated in cases of "amnesic shellfish poisoning" (ASP), in various regions of the globe, by production of domoic acid. Closest incidence of this also has been in southeastern Canada. In winter of 1987-88, on Prince Edward Island, 150 human cases of ASP (including four deaths) resulted from consumption of blue mussels; the source of contamination was apparently a massive bloom of *Nitzschia* (=*Pseudonitzschia*) *pungens* var. multiseries [13]. Another domoic acid producer, *P. pseudodelicatissima*, has been abundant in the nearby Bay of Fundy, which harbors extensive aquaculture operations. *Pseudonitzschia* and *Alexandrium* species also are monitored in the Gulf of Maine coastal waters [14]. Species of P*seudonitzschia* (*P. pungens, seriata, delicatissima*), closely related to those associated with ASP, have been abundant at times in New Jersey coastal and nearshore waters, especially during the fall and winter months [1,5].

Another dinoflagellate, *Dinophysis* spp., has been associated with diarrhetic shellfish poisoning (DSP). This is primarily gastroenteric and somewhat less severe than PSP or ASP, which include neurological symptoms. The DSP syndrome was first described in Japan, subsequently detected in Europe, and suspected to have occurred in New York [13]. Incidence in Japan implicated *D. fortii* as the causative agent; this is a warm-water species found in the Atlantic but primarily southward of New Jersey. Other implicated species, also found in the New York Bight, include *D.acuminata* and *D. norvegica*, both of which have been present in New Jersey coastal waters. A similar species, *D. acuta*, is a usual component of the shelf phytoplankton off New Jersey and, in June of 1978, bloomed along the entire Atlantic-northern Cape May County coastline, although no incidence of DSP was reported [1,12].

Other toxic syndromes, principally Ciguatera fish poisoning and neurotoxic shell- fish poisoning (NSP), have been associated with dinoflagellates that occur in tropical of subtropical waters. NSP, caused by *Gymnodinium breve*, has chiefly affected the marine biota through contact with the toxin in seawater. But humans have also been affected through ingestion of contaminated fish or shellfish or by aerosols from wind and wave action over extensive *G. breve* blooms. The FDA criterion for closure of waters to shellfishing is $5x10^3$ cells L^{-1} ($5ml^{-1}$) of *G. breve* [3], although visible red tide may not result from cell concentrations this low. The species historically has affected the Florida Gulf coast, causing extensive fish kills; however, occurrence in North Carolina in winter of 1987-88 extended its range (via the Gulf Stream) northward on the US Atlantic coast [13]. The latter event was associated with 48 cases of NSP in humans, plus the deaths of hundreds of bottlenose dolphins, many of which washed ashore in New Jersey. To our knowledge G. *breve* has not been detected in New Jersey waters. Ciguatera poisoning in humans typically follows consumption of contaminated finfish or shellfish that come from tropical or subtropical waters. At least five dinoflagellate species, including benthic varieties, have been implicated as ciguatera toxin producers [13], although none have been found in the New Jersey area [1a].

A newly described species or group of organisms, *Pfiesteria spp* (*P. piscicida*), has proven lethal to fish, causing lesions by production of exotoxin(s), in areas of the southeastern US. It has also been associated with serious neurotoxic effects on humans, either through direct contact with, or aerosols from affected waters. It is primarily a low-salinity species with an affinity for polluted or enriched estuaries with sluggish circulation. It was first implicated as a causative agent in extensive kills of various fishes (mostly menhaden) in North Carolina [15], subsequently in Maryland, and its presence has been documented as close to New Jersey as Indian River, Delaware. Its complex life cycle has several phases including dinoflagellate, ameoboid, benthic cyst and zoospore stages, thus rendering it difficult to identify from field samples using only light microscopy. In addition, they are rarely detected by water discoloration (red tide), as relatively low cell densities (10^2 - 10^3 ml^{-1}) are capable of producing large amounts of toxin [15]. The magnitude of the problem has prompted some government agencies to develop response protocols, with proper safety techniques for sampling, in the event of a *Pfiesteria* outbreak. For identification/confirmation, samples are referred to the research center at North Carolina State University [15]. For information regarding New Jersey's response contingency plan, the NJDEP Office of Policy and Planning should be contacted at (609) 292-1254.

A few other species, which are common or abundant in New Jersey waters, deserve increased attention as to their potential toxicity. *Olisthodiscus luteus* (a raphidophycean) is historically considered responsible for some of the red tide blooms in New Jersey's northern estuarine and coastal area [1,6]. Some species of this group have exhibited toxicity in various regions of the globe. *O. luteus* may be confused morphologically with *Heterosigma carterae*, which has undergone noxious blooms in other areas, including the west coast of North America. In British Columbia these have resulted in over 50 million dollars in losses of pen-reared salmon [14]. More definitive taxonomic investigation of the local species, and its effects on indigenous fauna, are needed. *Prorocentrum* spp. (*P. micans, minimum, triestinum*) are also historically responsible for red tides in New Jersey's northern estuarine and coastal areas. Extensive blooms dominated by *P. micans* along the Monmouth County shore (Sandy Hook to Belmar) from 1968 to 1972, and 1980 to 1982 were associated with respiratory discomfort to bathers, causing temporary closure of some public bathing beaches [2]. *Prorocentrum lima* (= *Exuviaella marina*), a benthic dinoflagellate, has been found in water column samples from New Jersey's coastal waters and from Barnegat Bay [1,5]. This species has been implicated as a source of DSP at commercial mariculture sites in Nova Scotia in the eastern Gulf of Maine region [14]. In Barnegat Bay, New Jersey in August 1987, a kill of several thousand blueclaw crabs was observed just west of Barnegat Inlet. *P. lima* was found abundant in a water sample taken at the site; in addition, pinkish coloration was observed on the crab gills, and on a submerged sandbar where the dead crabs were found [1a]. Also in Barnegat Bay, in 1964, another dinoflagellate, *Cochlodinium heterolobatum* caused a serious "red tide", which pervaded the central and upper bay (a > 15 mile segment) from early August to mid September. This event caused visible distress, and mortality, to several species of small fish and shellfish (collectively, a substantial component of the bay ecosystem) in shallow water, and created a very pungent odor [9]. *C. heterolobatum* elsewhere has been associated with adverse effects on oyster larvae [13]. In southern New Jersey coastal waters, extensive "green tides" caused by another dinoflagellate, *Gyrodinium* cf. *aureolum*, occurred in 1984 and 1985, and to a lesser degree in 1996 and 1997. During the earlier blooms, symptoms that developed in persons with prolonged exposure to the bloom water (e.g. lifeguards) included nausea, throat and eye irritation and congestion. A few isolated kills of crabs and mussels were observed coincident with bloom presence and some bottom hypoxia was detected in nearshore areas [2,9]. Two other species common throughout New Jersey's coastal waters. *Scripsiella trochoidea (=Protoperidinium trochoideum)* and, to a lesser degree, *P. brevipes,* have been found abundant, though not directly implicated, in certain cases involving apparent toxicity in other regions [14].

It is appropriate here to note that, although we focus on negative aspects, most marine algal species are not environmentally detrimental, and that many blooms (or red tides) are benign. As single-celled plants, phytoplankton play an integral role in the aquatic ecosystem. Comprising the most ubiquitous major group of primary producers, they form the basis of marine and estuarine food chains, ultimately sustaining our copious fishery resources. Serious impacts on human health, or on fisheries, notwithstanding, many instances of adverse effects of algae, or algae blooms, go either unnoticed or unreported. Few, if any, cause/effect investigations have been conducted in cases of fish kills or bather complaints, whether the mechanism is hypoxia, direct contact (with the microorganisms), irritant(s) or toxicant(s). This applies to the more dramatic, as well as obscure, situations. The aforementioned events involving *Ceratium tripos*, *Prorocentrum* spp., *Gyrodinium cf aureolum*, and the several other species (flagellates, diatoms and chlorophytes) whose chronic blooms have contributed to hypoxia or aesthetically unpleasant conditions, have been among the more obvious. Others such as the brown tides of *Aureococcus anophagefferens*, and their detrimental effects on shellfish growth, have been somewhat less obvious, although no less severe. New Jersey has been fortunate, thus far with few or no cases on record of acute toxicity from phytoplankton traced to its own waters. Continued monitoring, with expansion spatially and temporally to cover all potentially toxic areas, should aid considerably in maintaining this record.

Conclusions

No blooms of toxin producing algae were detected or observed in New Jersey waters during the summer of 1999. The only full to heavy algal bloom to occur in 1999 was the “brown tide” in the Barnegat Bay-Little Egg Harbor area.

Algal concentrations in Raritan and Sandy Hook Bays that are normally high remained at low to moderate levels through the 1999 season. Coastal waters sustained normally low to moderate levels.

Recommendations

Relocate current sampling stations to the nearest ambient nutrient monitoring network stations, so year-round nutrient data can be correlated with summer season phytoplankton species and bloom occurrences.

Additional stations are needed to better represent New Jersey’s shellfish harvestable waters.

Deployment of Datasondes to monitor dissolved oxygen levels on an hourly basis for 2-5 days should be required in areas where full or heavy blooms are occurring.

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Table 2. Major phytoplankton species found in the 1999 New Jersey coastal and estuarine survey, with notes on occurrence and distribution.

Diatoms	
Leptocylindrus danicus [3] *L. minimus*[3] * *Skeletonema costatum*[5]* *Cyclotella* sp. *[2,5] *Thalassiosira* sp. [5] *T. gravida* [5]* *T. nordenskioldii* [5]* *T. rotula* *Eucampia zoodiacus* *Cerataulina pelagica* [3]	*Chaetoceros* spp. [5] *Rhizosolenia* sp. [3]* *R. delicatula* *Asterionella glacialis*[5]* *Thalassionema nitzschioides* *Navicula* sp. *Nitzschia* sp. * *Pseudonitzschia seriata* *Cylindrotheca closterium*[2]
Dinoflagellates	
P. micans [1,5] *P. triestinum* (= *P. redfieldi*) *Prorocentrum minimum* [1,5] *Gymnodinium* spp. [2] *Gyrodinium* spp. [2,5]	*G. aureolum* *G. estuariale* *Katodinium rotundatum**[1,5] *Heterocapsa triquetra* [2,5] *Oblea rotunda* *Protoperidinium trochoideum*
Other Phytoflagellates	
Olisthodiscus luteus[1,5] (=*Heterosigma carterae*) *Calycomonas ovalis**[4] *Chrysochromulina* sp.[2] *Pyramimonas* spp.[2] *Tetraselmis* sp.[2]	*Euglena* sp. (proxima *Eutreptia lanowii* *E. virdis* *Cryptomonas* sp. *Chroomonas amphioxeia* *C. minuta* *C. vectensis*
Nonmotile Coccoids	
*Aureococcus anophagefferens***[4,6]	*Chlorella* spp.* *Nannochloris atomus***[4]

*denotes species which were dominant or abundant, exceeding cell concentrations of 10^3 ml^{-1} at some time during the sampling period.

**denotes species which bloomed, approaching or exceeding 10^4 cells ml^{-1}. For *Nannochloris* and *Aureococcus*, because of their minute size (1.5-3.5 µm), this criterion is increased by a factor of ten, to 10^5. Other species listed occurred commonly, although not usually in abundance. Notes on spatial and temporal distribution of dominants are included.

Footnotes:

1. historically responsible for red tides in the region.
2. primarily estuarine.
3. primarily coastal.
4. most predominant in Barnegat Bay producing brownish water discoloration.
5. most abundant in Raritan/Sandy Hook Bay and adjacent NJ coastal waters; sometimes abundant in more southern areas (e.g. Barnegat Bay) and nearby New York waters.
6. has been responsible for brown tide blooms in eastern Long Island embayments, with damage to shellfish crops; in 1995, found in NJ for the first time in bloom proportions; bloomed again in 1997 and 1999.
7. responsible for green tides at the southern New Jersey coast in 1984-85 and to a lesser extent in 1996 and 1997.

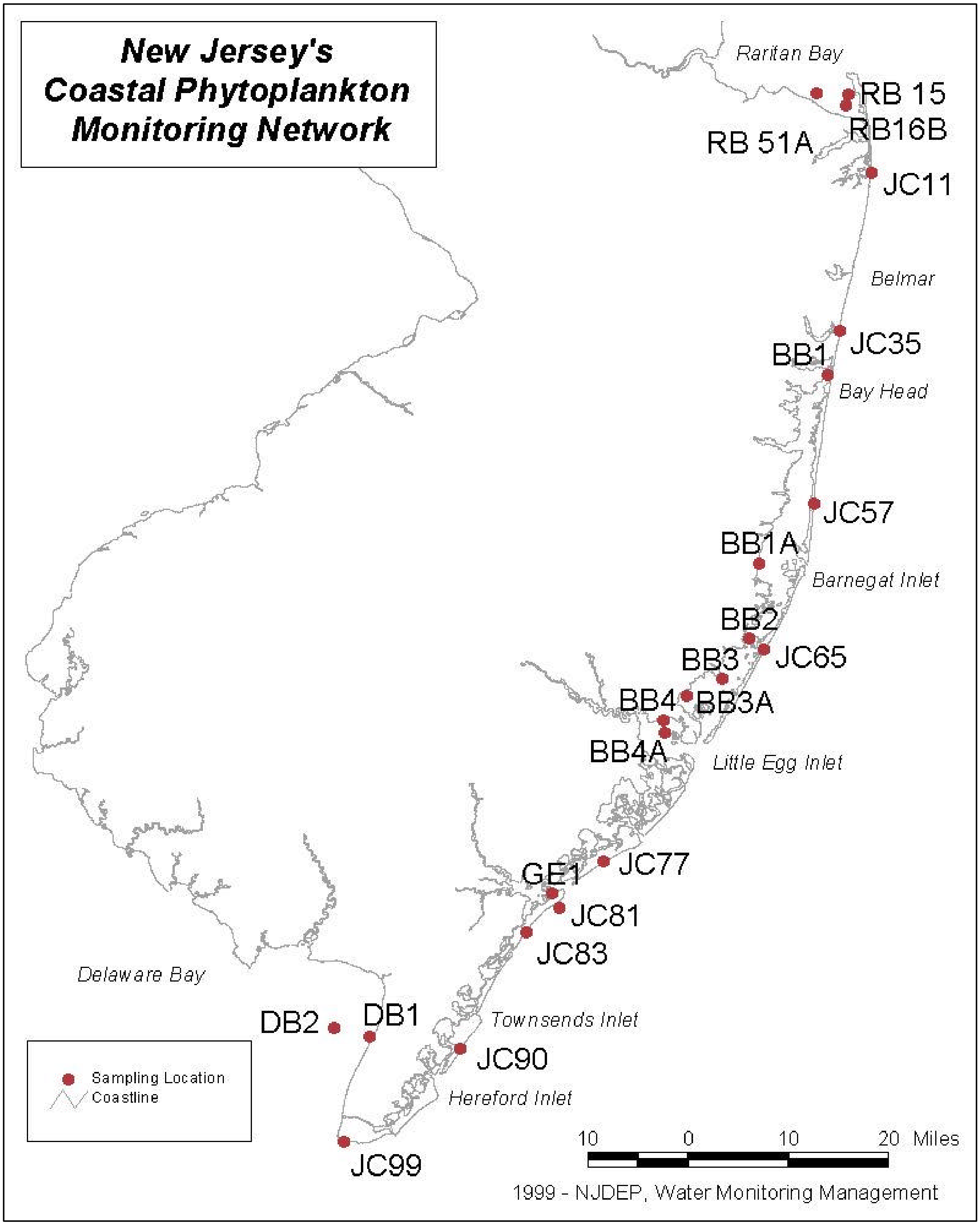


Figure 1. Locations of phytoplankton monitoring stations.

Table 3. Chlorophyll a (µg/L) for the 1999 New Jersey Coastal and Estuarine Phytoplankton Survey.

HUDSON/RARITAN	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
RB15	29.01	44.15	20.6	28.17	15.98	9.67	16.82	**23.49**
RB16B		55.08		20.6		10.09		**28.59**
RB51A	47.51		19.76	25.23	43.31		16.4	**30.44**
MEAN	**38.26**	**49.62**	**20.18**	**24.67**	**29.65**	**9.88**	**16.61**	

MONMOUTH CO. COAST	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
JC11	16.82			9.67	4.63	2.10	3.78	**7.40**
JC35	1.68	0.42	2.52	5.47	2.94	<0.42	2.94	**2.66**
MEAN	**9.25**	**0.42**	**2.52**	**7.57**	**3.79**	**2.10**	**3.36**	

OCEAN CO. COAST	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
JC57	0.84				0.84		10.51	**4.06**
JC65				3.78		14.72		**9.25**
MEAN	**0.84**			**3.78**	**0.84**	**14.72**	**10.51**	

BARNEGAT BAY	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
BB1	2.52	4.17	27.38	7.99	36.79	14.72	17.66	**15.89**
BB1A	3.36	19.71	34.76		15.56	12.19	15.14	**16.79**
BB1B				17.60				**17.60**
BB2	11.35	39.18	62.57	15.14	12.19	8.41	11.77	**22.94**
BB3	17.24	6.40	27.56		2.10	7.57		**12.17**
BB3A	1.26	29.67	37.47	5.89	7.57			**16.37**
BB4		12.79	39.52	7.15				**19.82**
BB4A		16.83						**16.83**
MEAN	**7.15**	**18.39**	**38.21**	**10.75**	**14.84**	**10.72**	**14.86**	

GREAT EGG HARBOR BAY	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
GE1		2.67						**2.67**
MEAN		**2.67**						

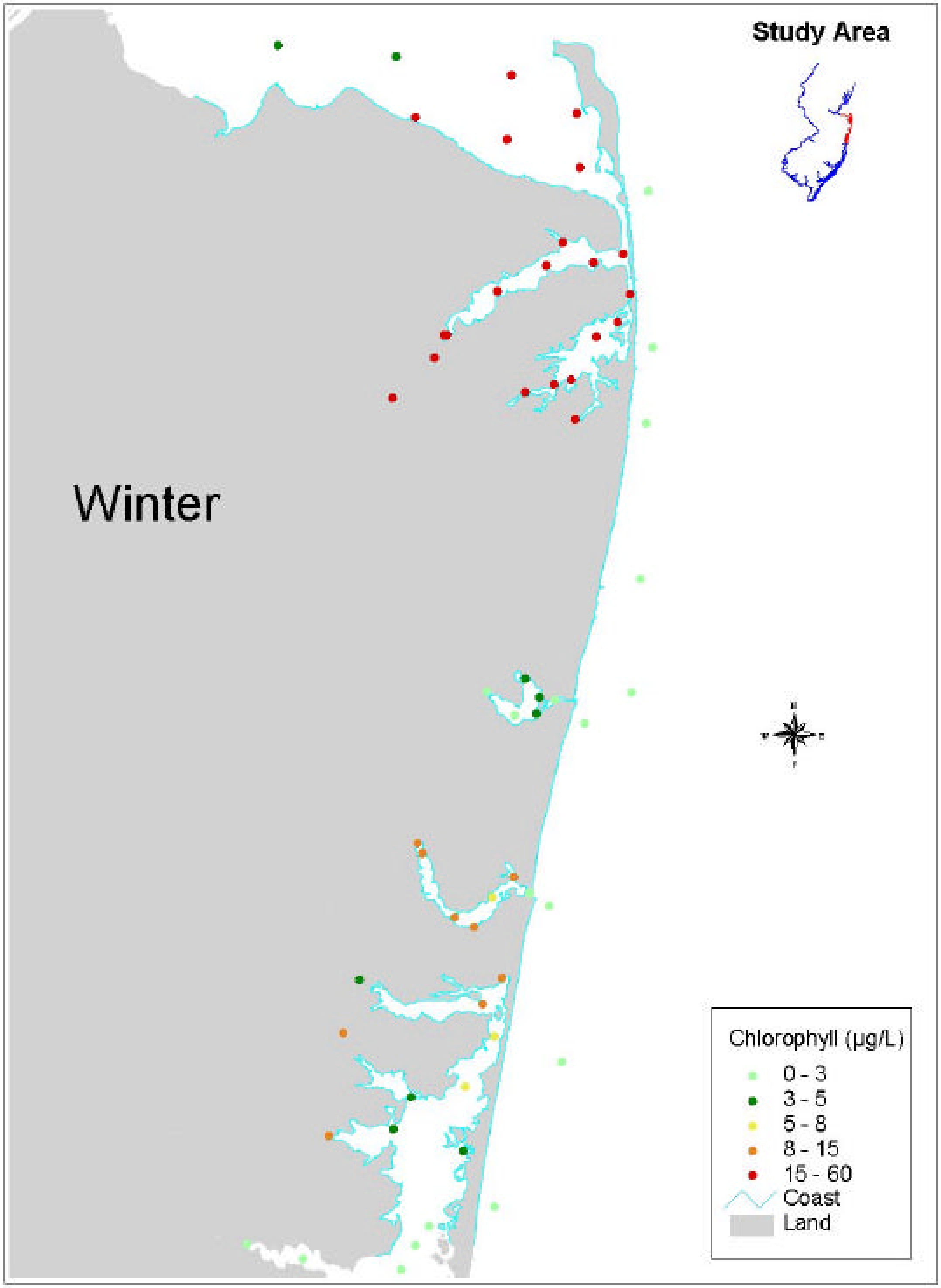
ATLANTIC/CAPE MAY CO. COAST	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
JC77		<0.42	2.10		1.68	13.03		**5.60**
JC81		<0.42						**<0.42**
JC83	1.26		2.10	0.84		3.78		**2.00**
JC90					<0.42			**<0.42**
JC99		6.73						**6.73**
MEAN	**1.26**	**6.73**	**2.10**	**0.84**	**1.68**	**8.41**		

DELAWARE BAY

	27-May	16-Jun	30-Jun	14-Jul	28-Jul	11-Aug	25-Aug	MEAN
DB1	18.50							**18.50**
DB2		9.51	12.02	31.54	48.35	42.47		**28.78**
MEAN	**18.50**	**9.51**	**12.02**	**31.54**	**48.35**	**42.47**		

Maps of Seasonal Chlorophyll a Levels from the Bureau of Marine Water Monitoring's Estuarine Monitoring Network

Winter Averages in Chlorophyll "a" values in the Raritan Bay region of New Jersey's marine waters for July 1998 to October 1999



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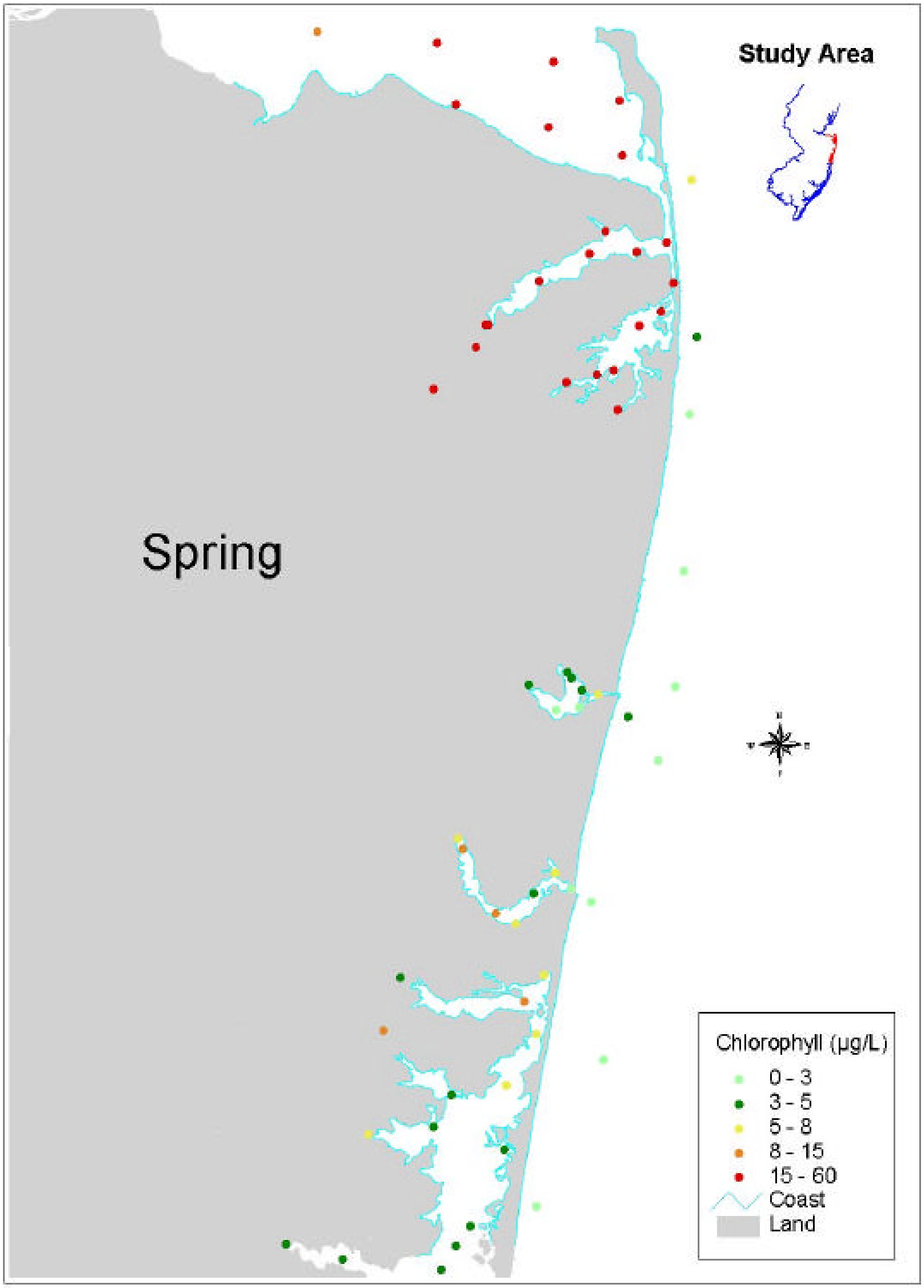
Spring Averages in Chlorophyll "a" values in the Raritan Bay region of New Jersey's marine waters for July 1998 to October 1999



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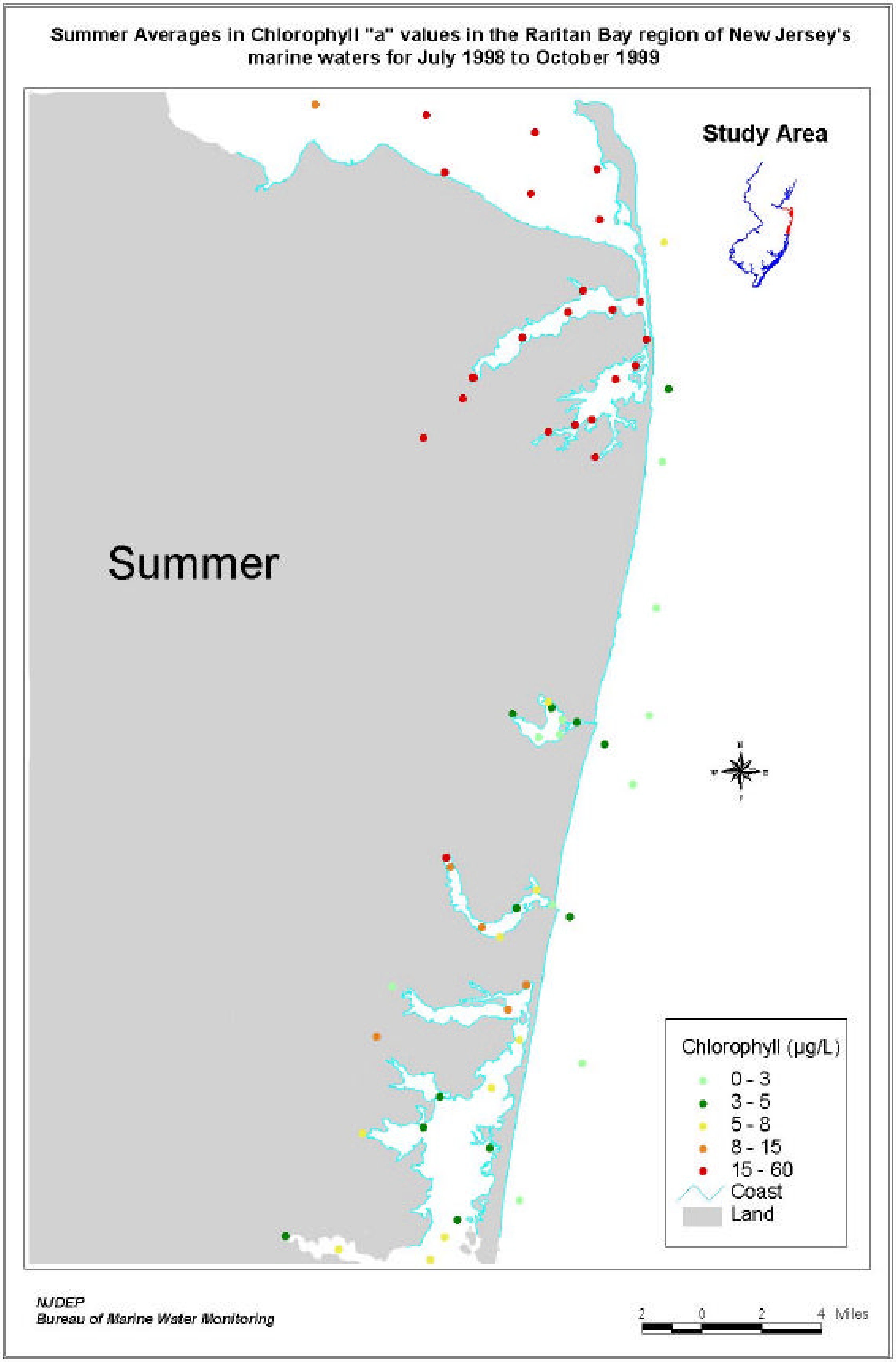
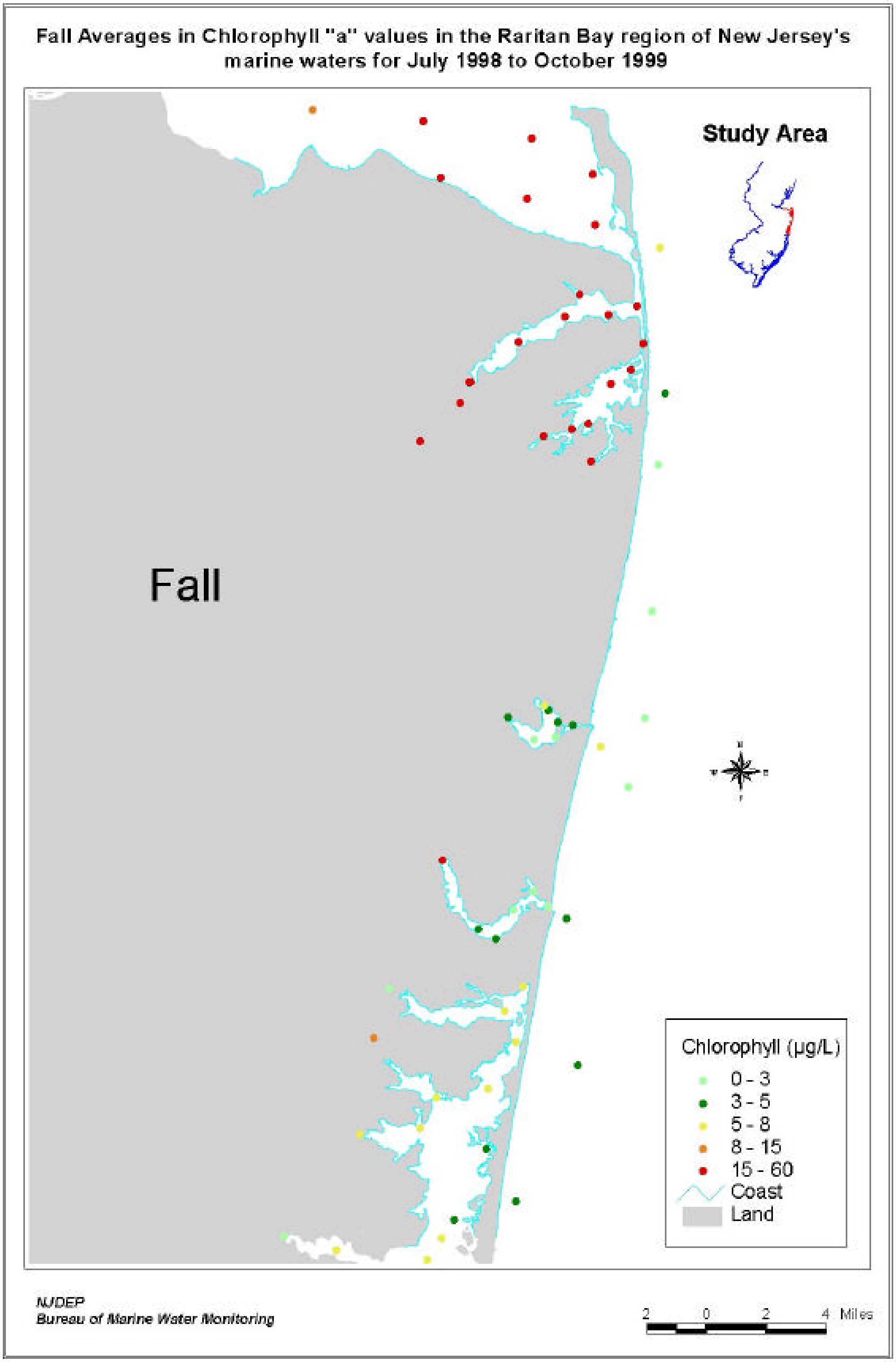
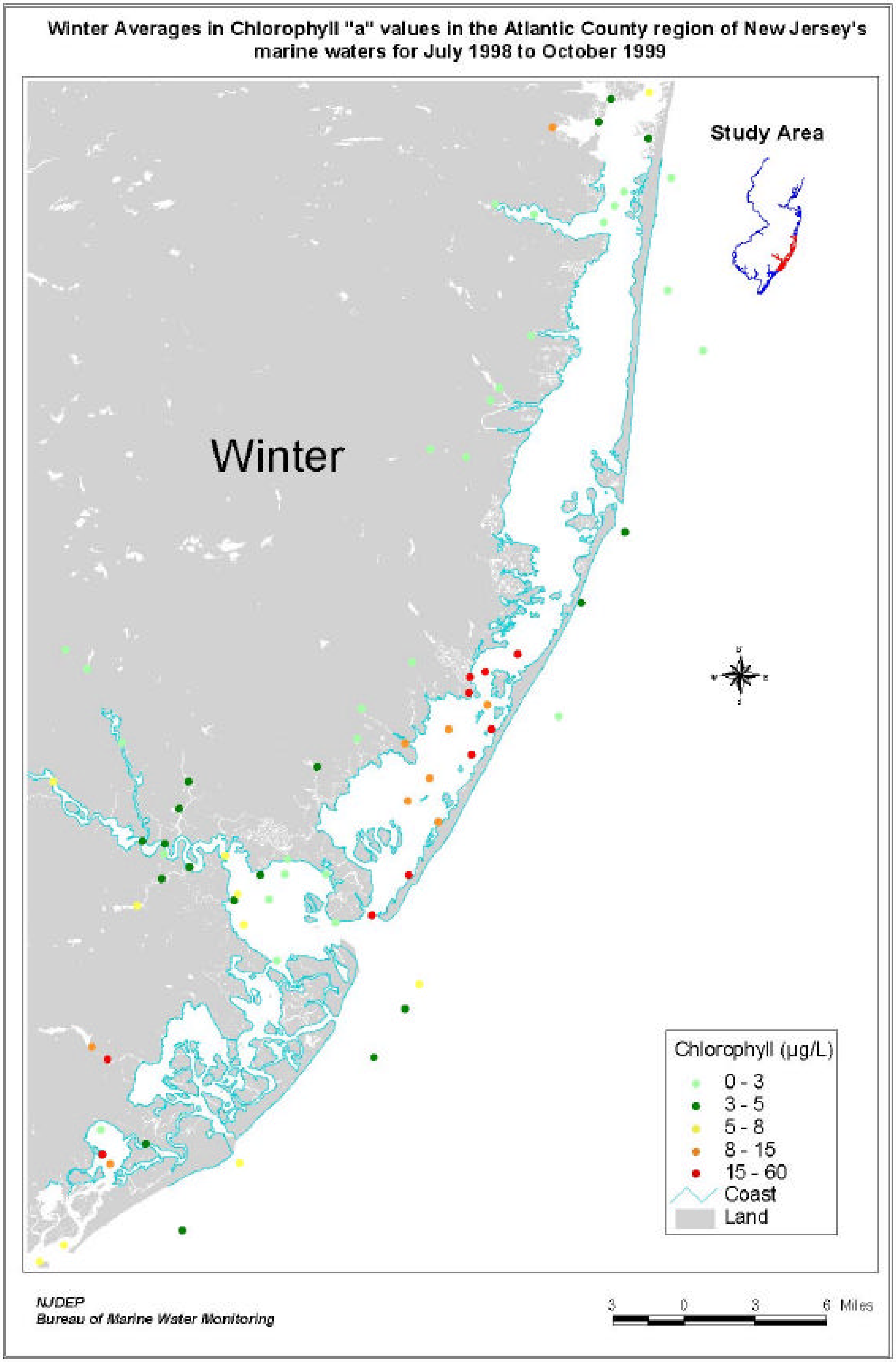
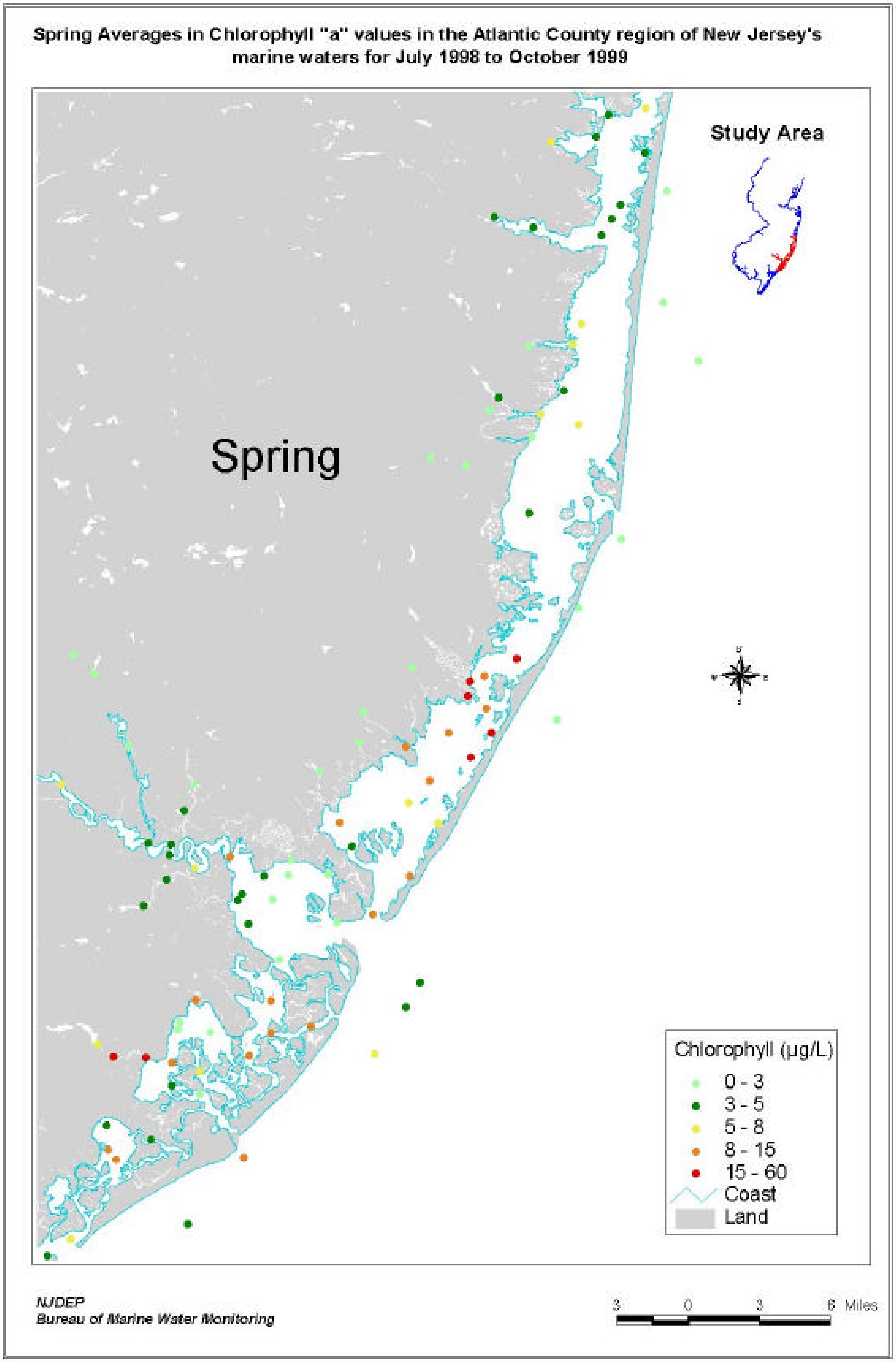
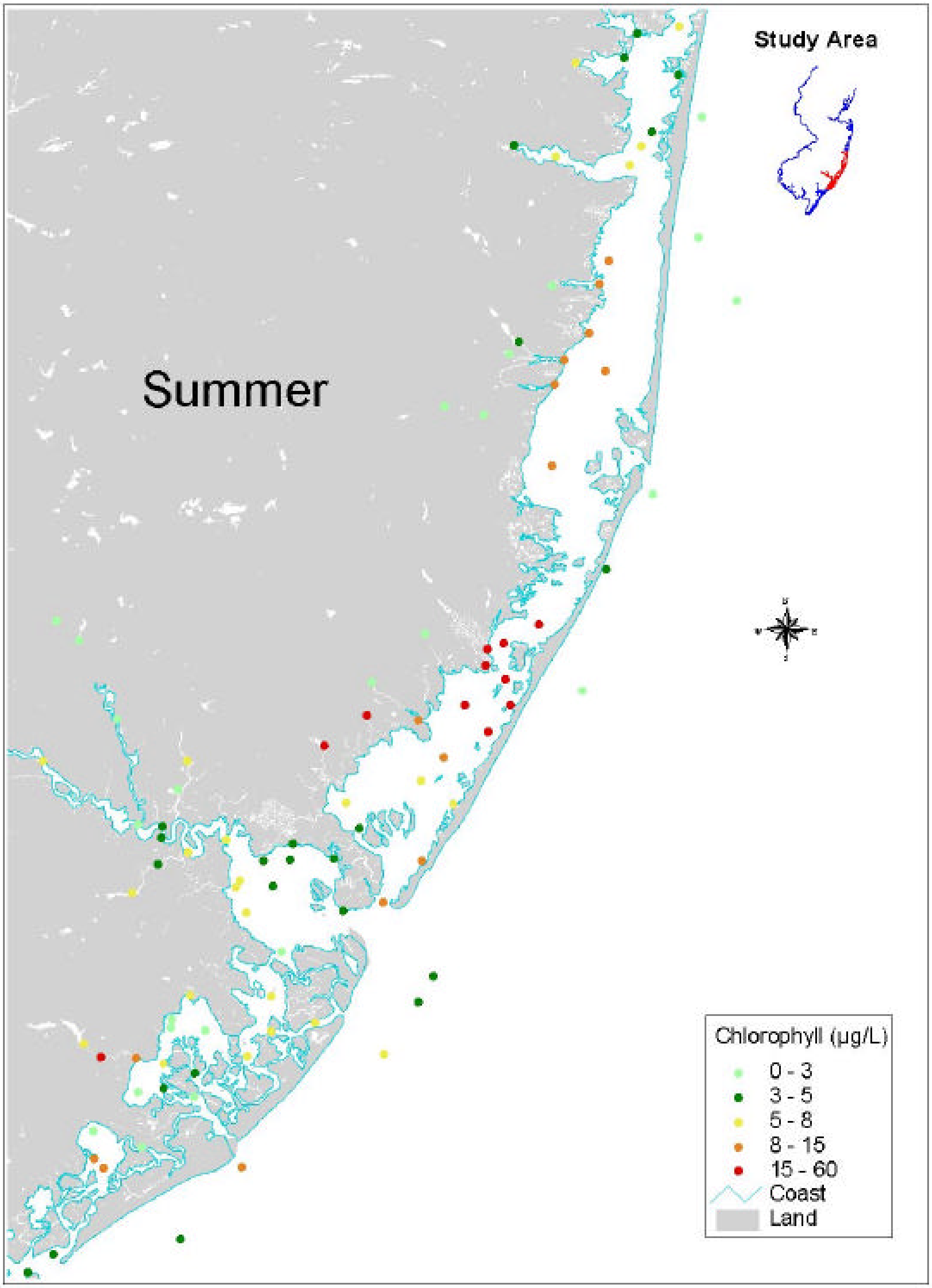

Summer Averages in Chlorophyll "a" values in the Raritan Bay region of New Jersey's marine waters for July 1998 to October 1999
Study Area
Summer
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
NJDEP
Bureau of Marine Water Monitoring
2 0 2 4 Miles


Fall Averages in Chlorophyll "a" values in the Raritan Bay region of New Jersey's marine waters for July 1998 to October 1999
Study Area
Fall
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
NJDEP
Bureau of Marine Water Monitoring
2 0 2 4 Miles

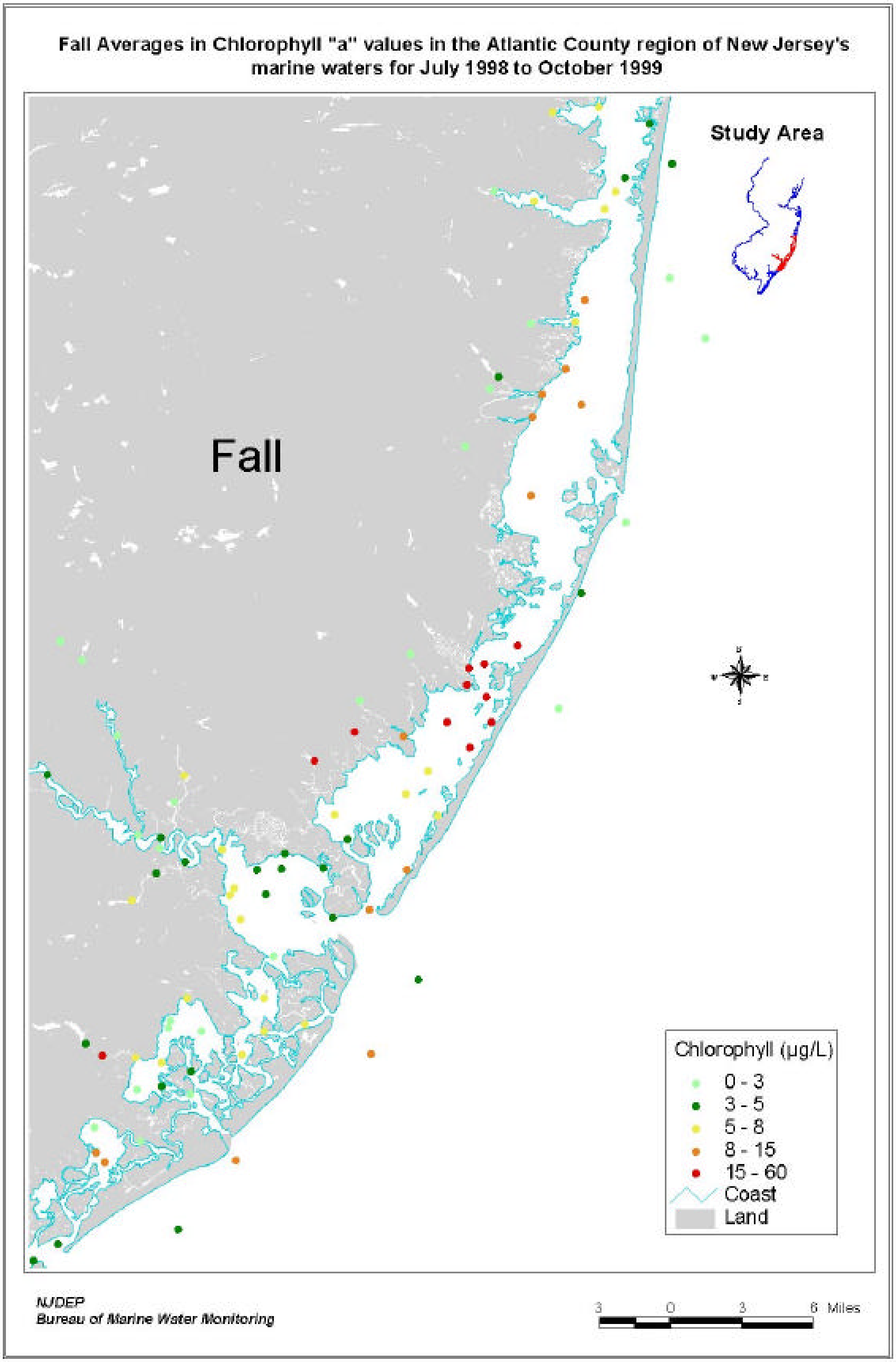

Winter Averages in Chlorophyll "a" values in the Atlantic County region of New Jersey's marine waters for July 1998 to October 1999
Study Area
Winter
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
NJDEP
Bureau of Marine Water Monitoring
3
0
3
6 Miles


Spring Averages in Chlorophyll "a" values in the Atlantic County region of New Jersey's marine waters for July 1998 to October 1999
Study Area
Spring
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
NJDEP
Bureau of Marine Water Monitoring
3
0
3
6 Miles

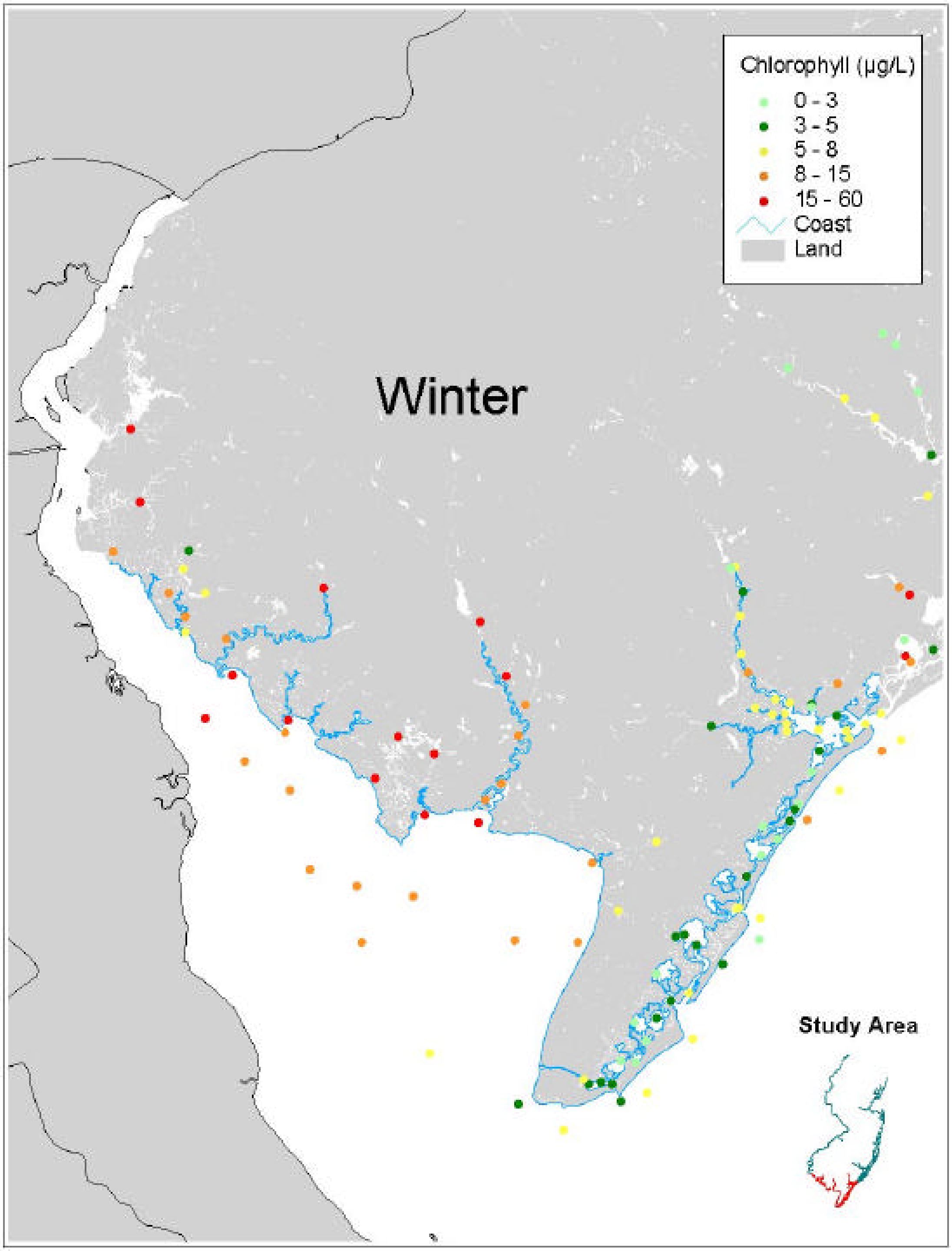
Summer Averages in Chlorophyll "a" values in the Atlantic County region of New Jersey's marine waters for July 1998 to October 1999



NJDEP
Bureau of Marine Water Monitoring

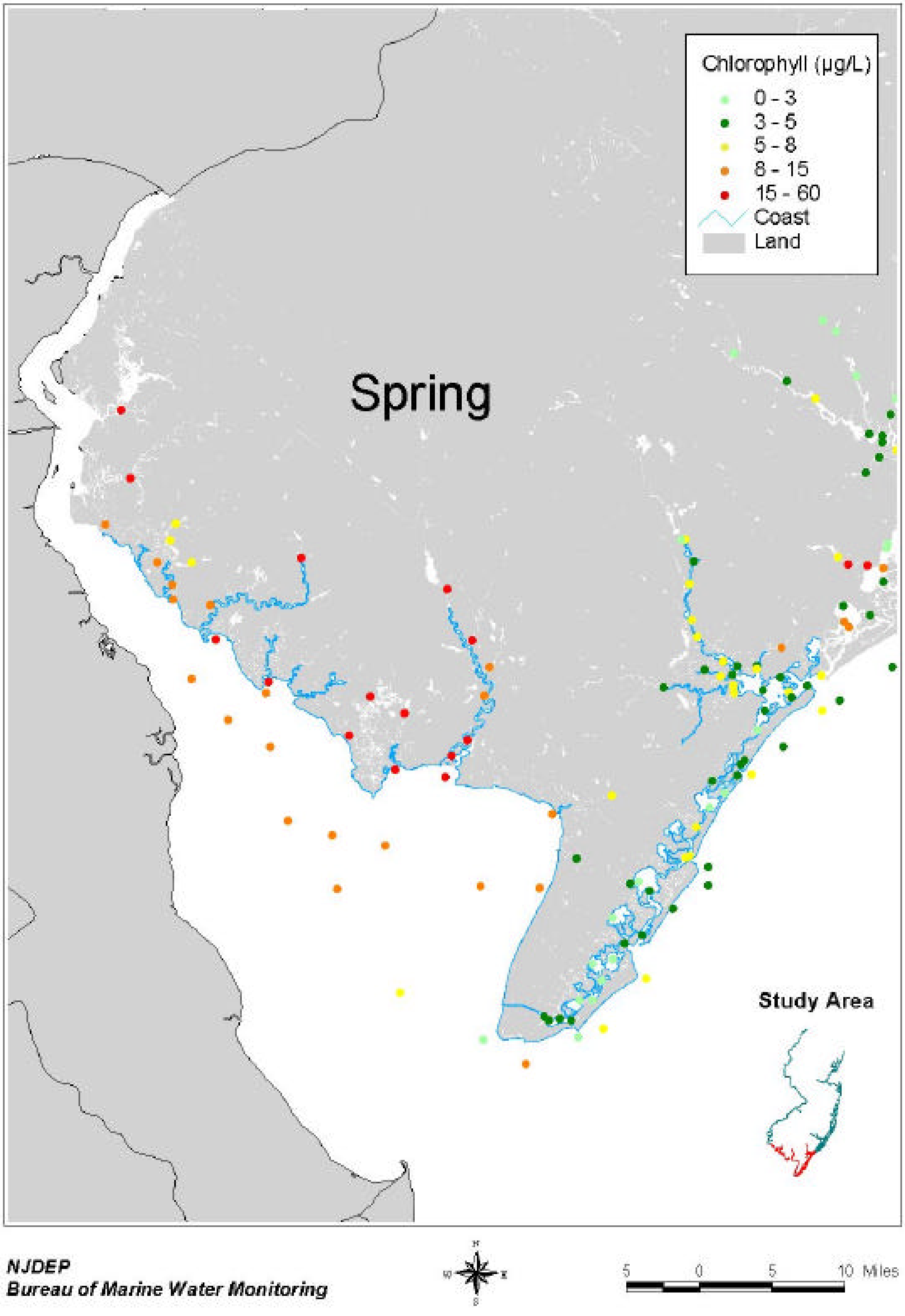

Fall Averages in Chlorophyll "a" values in the Atlantic County region of New Jersey's marine waters for July 1998 to October 1999
Study Area
Fall
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
NJDEP
Bureau of Marine Water Monitoring
3 0 3 6 Miles

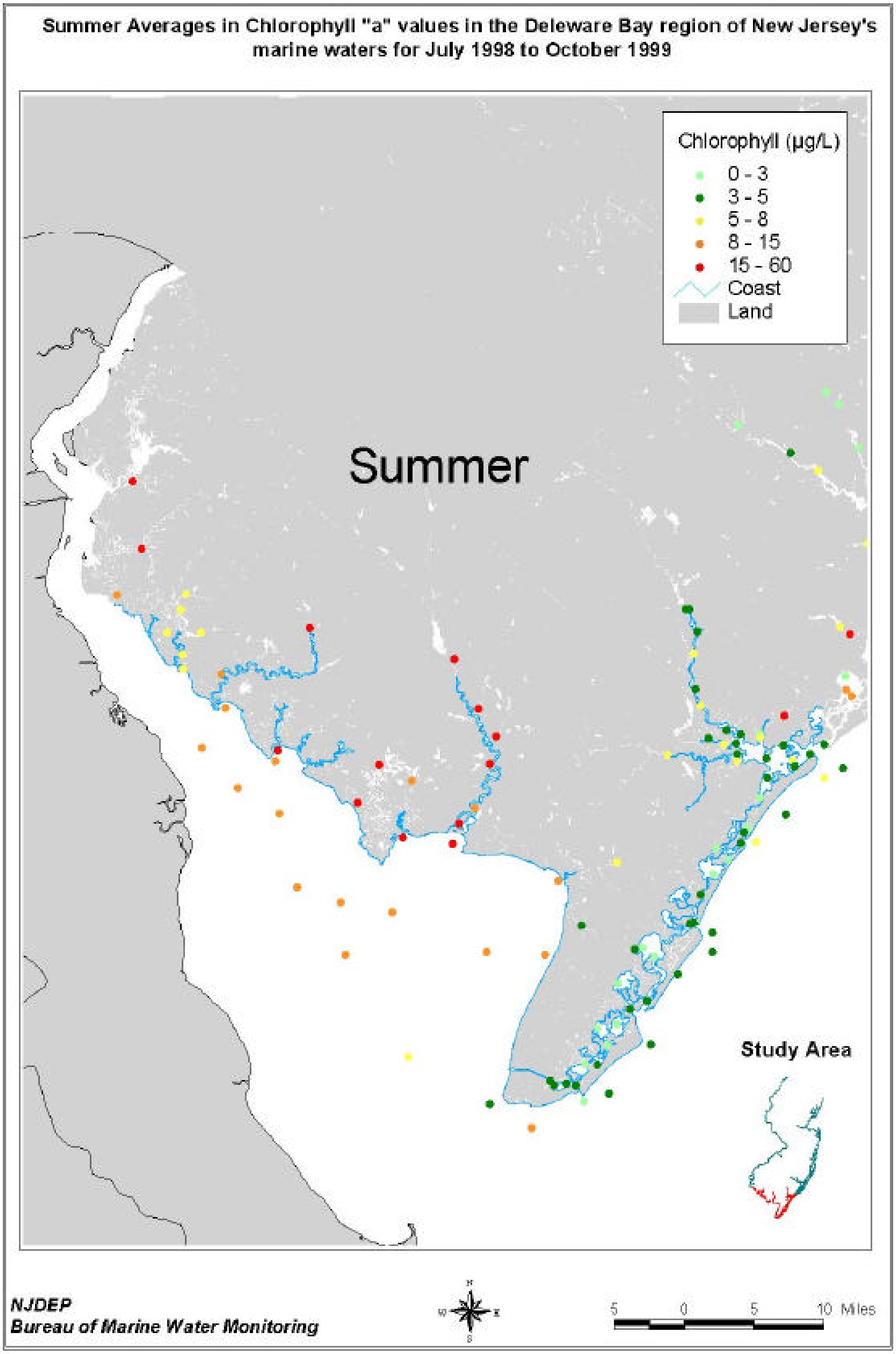
Winter Averages in Chlorophyll "a" values in the Deleware Bay region of New Jersey's marine waters for July 1998 to October 1999



NJDEP
Bureau of Marine Water Monitoring

Spring Averages in Chlorophyll "a" values in the Deleware Bay region of New Jersey's marine waters for July 1998 to October 1999




Summer Averages in Chlorophyll "a" values in the Deleware Bay region of New Jersey's marine waters for July 1998 to October 1999
Summer
Chlorophyll (µg/L)
0 - 3
3 - 5
5 - 8
8 - 15
15 - 60
Coast
Land
Study Area
NJDEP
Bureau of Marine Water Monitoring
5 0 5 10 Miles

Fall Averages in Chlorophyll "a" values in the Deleware Bay region of New Jersey's marine waters for July 1998 to October 1999